

Genesis Capsule Yields Solar Wind Samples

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NASA's Genesis capsule, carrying the first samples ever returned from beyond the Moon, took a hard landing in the western Utah desert on 8 September after its parachutes failed to deploy. Despite the impact, estimated at 310 km per hour, some valuable solar wind collector materials have been recovered. With these samples, the Genesis team members are hopeful that nearly all of the primary science goals may be met.

The Genesis spacecraft was launched in August 2001 to collect and return samples of solar wind for precise isotopic and elemental analysis. The spacecraft orbited the Earth-Sun Lagrangian point (L1), ~1.5 million km sunward of Earth, for 2.3 years. It exposed ultrapure materials—including wafers of silicon, silicon carbide, germanium, chemically deposited diamond, gold, aluminum, and metallic glass—to solar wind ions, which become embedded within the substrates' top 100 nm of these materials.

The spacecraft jettisoned the capsule laden with samples as it flew by Earth on 8 September. The capsule was to deploy a drogue parachute and then a parasail, which was to be snagged by helicopter to prevent any damage to the collection wafers upon landing. The capsule was not designed to be aerodynamically stable at subsonic speeds. It began tumbling as it neared the ground, and hit the ground edge on (Figure 1).

A review board is investigating the cause of the mishap. Preliminary findings point to an incorrectly installed accelerometer, which was unable to sense the deceleration upon re-entry and initiate the parachute deployment sequence.

Teams from the NASA Johnson Space Center, the Jet Propulsion Laboratory, Lockheed Martin Astronautics, and the U.S. Department of Energy's Los Alamos National Laboratory spent several weeks carefully disassembling the damaged sample canister in a clean room at Dugway Proving Grounds, Utah. A large fraction of the collection wafers were broken by the impact, but fortunately the samples that survived best were ones designed to address the top science priorities of the mission.

Three target wafers of the electrostatic solar wind concentrator survived intact, with parts of the fourth wafer also intact (Figure 2a). These targets will be analyzed for oxygen isotope ratios with a desired measurement accuracy of $\pm 0.1\%$, a factor of nearly 100 better than the current $^{18}\text{O}/^{16}\text{O}$ data, and the first ever measurement of solar wind $^{17}\text{O}/^{16}\text{O}$. These data should help understand what processes contributed to the heterogeneity of oxygen isotopic abundances among meteorites and planetary bodies early in solar system history.

Sample collectors intended to address mission priorities 2 and 3 fared equally well. A large (~220 x 100 mm) gold foil intended for nitrogen isotopic analysis appeared nearly unaffected by the impact (Figure 2b). A similarly



Fig. 1. Genesis capsule shortly after impact. The heat shield is on the left side, with the parachute deck on the right. Part of the sample canister can be seen between near ground level. The capsule was ~1.5 m diameter. Photo courtesy of NASA/Johnson Space Center. Original color image appears at back of this volume.

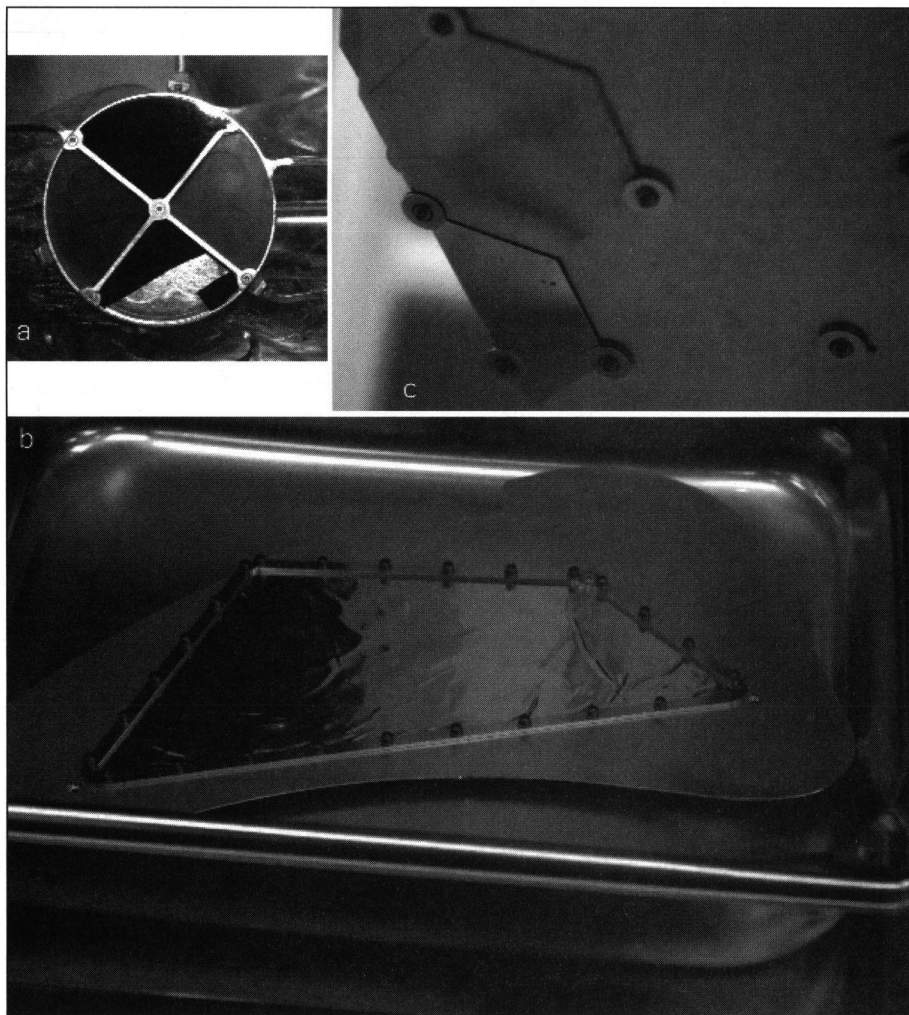


Fig. 2. Some of the best surviving solar wind collectors will address Genesis's top science priorities. (a) Concentrator target, 6-cm diameter. (b) Gold foil, 10 x 22 cm. (c) Four-centimeter full- and half-hexagon collector wafers on the edge of a mostly empty array. Photos courtesy of NASA/Johnson Space Center. Original color image appears at back of this volume.

sized aluminum foil intended for noble gas analyses was crumpled, but completely recovered.

The solar nitrogen isotopic composition is currently unknown because solar-wind-rich lunar samples display a puzzling range of over 30% in their nitrogen isotopic compositions. While solar wind noble gas measurements have also been made on lunar samples, the Genesis noble gas results will be free of lunar regolith artifacts.

An equally high priority is to understand and quantify solar wind isotopic fractionation. The magnitude of solar wind isotopic fraction is currently unresolved, but it has strong implications for how all Genesis results are interpreted in relation to solar compositions.

To address this question, separate samples of coronal-hole and interstream wind were collected. Precise helium isotope analyses in these separate solar wind regimes should confirm or refute Coulomb drag models of solar wind isotopic fractionation and define the

relationship between solar wind and solar isotopic compositions.

The regime-specific arrays consisted entirely of wafers of semiconductor materials, which were the most badly damaged during the impact. Overall, silicon and germanium collectors were only found as relatively small shards, while sapphire wafers survived as larger pieces with several intact wafers found (e.g., Figure 2c). Fortunately, wafers were coded by thickness, so that measuring the wafer's thickness will tell which solar wind regime it was exposed to.

While analysis of regime-specific solar wind must be done on wafer fragments, this is still very feasible, allowing exact quantification of any isotopic differences between solar wind regimes.

Great care was taken during assembly of the payload to ensure the cleanest possible conditions so contamination would not overwhelm the rarified solar wind trapped just under the surface (solar wind oxygen collected over 2.3 years amounts to only 0.5 nanograms/

cm²). The samples were expected to return in pristine condition, requiring no surface cleaning prior to most analyses.

The capsule's impact resulted in significant contamination to many samples and some contamination of all samples. While some analysis techniques, such as noble gas mass spectrometry, are immune to contamination, other techniques will require surface cleaning prior to analysis.

The earliest Genesis results should be reported within 6 months. As with all sample return missions, though, there is no time limit on analyses, so Genesis samples should continue to yield results for years to come.

—ROGER C. WIENS, Los Alamos National Laboratory, New Mex.; DONALD S. BURNETT, California Institute of Technology, Pasadena, Calif; and EILEEN K. STANSBERY and KAREN M. MCNAMARA, Johnson Space Center, Houston, Tex.

For additional information, contact R. C. Wiens; E-mail: rwiens@lanl.gov.

MEETINGS

The Life Cycle of Continental Rifting as a Focus for U.S.-African Scientific Collaboration

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The East African Rift System (EARS) provides the unique opportunity, found nowhere else on Earth, to investigate extensional processes from incipient rifting in the Okavango Delta, Botswana, to continental breakup and creation of proto-oceanic basins 3000 km to the north in the Afar Depression in Ethiopia, Eritrea, and Djibouti. The study of continental rifts is of great interest because they represent the initial stages of continental breakup and passive margin development, they are sites for large-scale sediment accumulation, and their geomorphology may have controlled human evolution in the past and localizes geologic hazards in the present.

But there is little research that provides insights into the linkage between broad geodynamic processes and the life cycle of continental rifts: We do not know why some rifts evolve into mid-ocean ridges whereas others abort their evolution to become aulacogens. Numerous studies of the EARS and other continental rifts have significantly increased our understanding of rifting processes, but we particularly lack studies of the embryonic stages of rift creation and the last stages of extension when continental breakup occurs.

A recent U.S.-Africa workshop on anatomy of continental rifts, sponsored by the U.S. National Science Foundation's (NSF) Office of International Science and Engineering, was held last June, following an international meeting on the "East African Rift System: Geodynamics, Resources, and Environment" (extended

abstracts posted at www.gl.rhul.ac.uk/ear_conference/).

About 50 geoscientists from Africa, the United States, and Europe participated in the workshop to (1) identify critical research gaps that may exist in our understanding of the coupling of internal and external processes operating during different stages of rift evolution; (2) discuss existing geological and geophysical databases and determine what additional data are required to elucidate the larger-scale lithospheric and asthenospheric structure; and (3) build strong research collaborations between U.S., European, and African scientists that can overcome the political and national boundaries that hinder scientific progress.

Because of logistical difficulties, studies of the EARS have typically been undertaken in isolation by various universities and research groups focusing on isolated segments of the rift system. In contrast, an international collaborative research effort fully involving African scientists is required if continental rifting processes are to be understood.

The workshop provided a forum for discussion with African scientists on how science funding is allocated in the United States and Europe. The meeting highlighted the dilemma that NSF funds support process-driven scientific inquiry based on academic peer review, whereas African countries need science that addresses societal needs, including geohazards, resources, and environmental issues. For example, U.S. scientists (and African colleagues) are intrigued by the Afar Depression in northern Ethiopia as a

place to study the fundamental scientific issue of how the lithosphere evolves during the transition from continent-to-ocean rifting, whereas African funding sources require that African scientists focus on geothermal resources, earthquake hazards, and potential epithermal gold deposits.

A second major concern for African participants is the great need to strengthen the capacity of African universities in research and education (ideally through a closer linkage with U.S. and European universities, and particularly via increased interaction between young U.S., European, and African scientists). Africa has a critical need for a larger scientific workforce for its natural resource sector, and collaborative efforts need to establish opportunities for training African scientists and technicians. One model for such efforts that balances academic and societal interest, and that explicitly provides for capacity building, is the nascent "AfricaArray" (http://spall.geosc.psu.edu/Nyblade/Africa_Array/) that aims to create a self-sustaining seismic array in every participating African country over the next decade. Scientific issues were discussed on both a geographic and a disciplinary basis. The EARS can be geographically and tectonically divided into the Afar Depression and Red Sea (oceanic and incipient oceanic rifting); the Main Ethiopian Rift and Turkana Depression (transitional between "typical" continental and oceanic rifting styles); the Kenyan and Western Rifts (classic intracontinental rifts); and the Southwestern (Okavango) Rift (extension has barely commenced and classic geomorphic rift features are as yet lacking).

Research Needs and Opportunities Identified

Although decades of scientific studies have significantly improved the understanding of the different branches of the EARS, significant knowledge and data gaps remain in many areas. Some key questions and opportunities were identified and are discussed below.

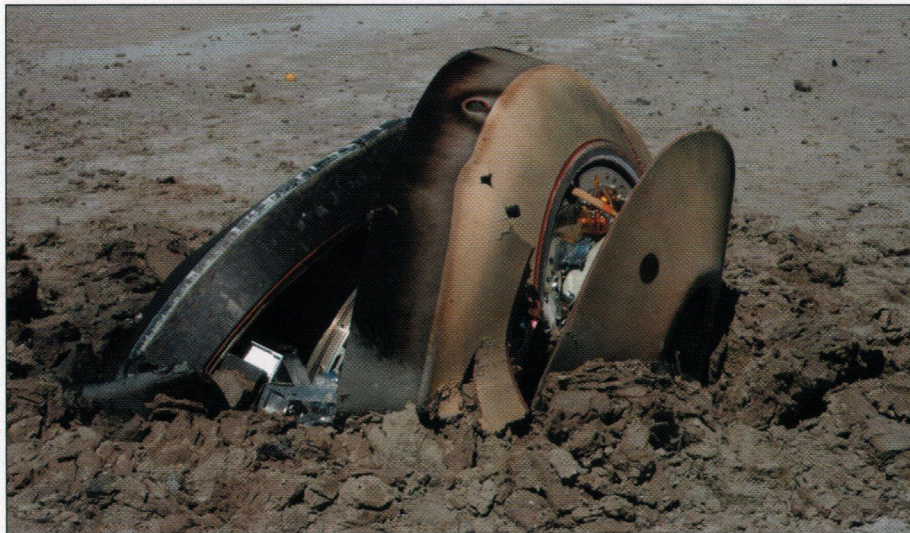


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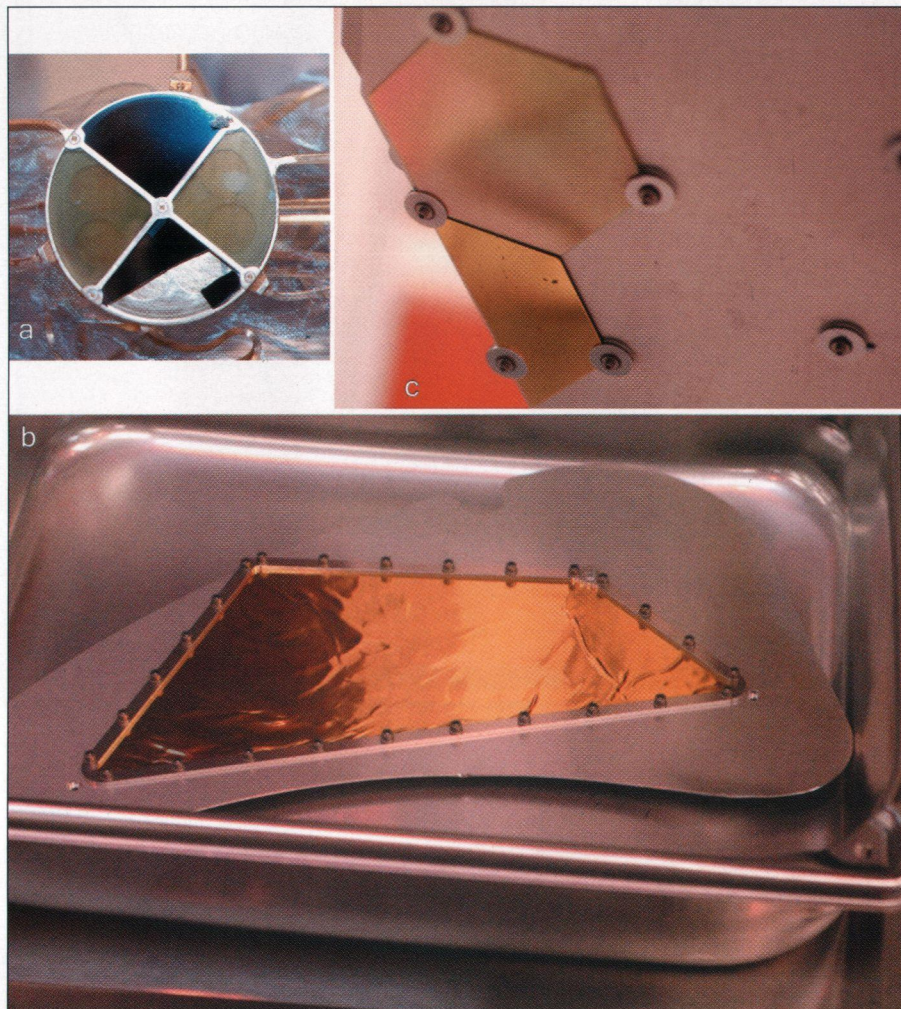


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